DESIGN OF THE TARGET FOR ^{99}MO PRODUCTION IN THE ELECTRON LINEAR ACCELERATOR

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The design of both the target system and the shipper container for liquid ^{99}Mo and ^{99m}Tc imposes stringent requirements on the target material, the primary vessel of shipping container and the regulations for work after production of these isotopes in the accelerator by a high-power photon beam [1]. The target wall material and the material of the shipping-container primary vessel must not interact with the NaOH solution. This is due to the fact that the solution of molybdenum in NaOH is used as a target, and this makes it possible to simplify the process of radiochemical separation of ^{99}Mo and ^{99}Tc [2]. Nickel and palladium appear to be most suitable for the purpose. However, palladium is a very expensive material, and nickel has a high residual induced activity; so, nickel and stainless steel would not do for target wall materials. The level of induced activity in titanium was calculated for the electron beam energy of 25 MeV and the average electron beam current of 0.8 mA after 60-hour irradiation. The induced activity level was assumed to be due to the reaction

$$^{48}\mathrm{Ti} + \gamma \rightarrow {}^{47}\mathrm{Sc} + \mathrm{p}.$$

Estimates of ^{47}Sc production were made for the titanium cylinder, 10 cm in diameter and 0.1 cm thick. The level of induced activity on the cylinder surface is predicted to be about 1 rem/h. The half-life period of ^{47}Sc is 81.6 hours.

The interaction of the NaOH solution with stainless steel was being investigated during a month at S.T.P. A flocculent precipitate appeared in the NaOH solution. A similar precipitate appeared in the NaOH solution of titanium welded joints. Only the solution of chemically pure titanium showed no precipitate. Moreover, titanium has the advantage over stainless steel and nickel as it has a lesser residual induced activity. So, titanium was chosen as a material for the target wall and the primary vessel.

The induced activity of natural molybdenum specimens after turning-off of beam was investigated to establish the regulations for work with irradiated specimens. According to ref. [3], long-lived isotopes are produced after 100-hour irradiation of natural molybdenum in the following proportion

^{99m}Te	^{99}Mo	^{93m}Mo	^{91}Mo	^{91m}Mo	^{90}Mo	time after the turn-off (h)
100	500	3200	1000	600	200	0
100	91	2			0,2	48
100	99	0,1				72

^{93m}Mo radiates gamma-quanta of energies up to 1.5 MeV. This calls for the increase in the thickness of the container shield. Calculations have shown that the shield weight of the container comprising a 1*l* primary vessel and having a 1 Ci increases in this case from ~ 100 to 700 kg. Therefore, instead of the problem of radiochemical separation we are facing the transport problem.

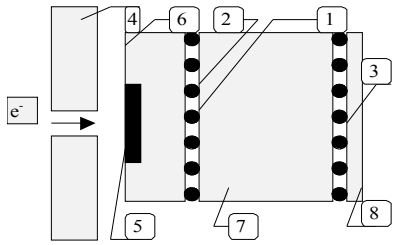

Fig.1. 1,2,3- molybdenum wires; 4- collimator; 5 - tantalum converter; 6,7,8- copper absorbers.

The 22 MeV linear accelerator was used in experiments. Natural molybdenum was irradiated by bremsstrahlung. Fig. 1 shows the experimental layout. After the titanium foil of the accelerator the electron beam has a divergence of $5 \cdot 10^{-2}$. The aluminum collimator is about 50 mm long, its inside diameter ~ 5 mm. Emerging from the collimator, the electron beam is incident on 2 mm tantalum converter and 8 mm copper absorber of electrons. The natural molybdenum wires were arranged perpendicular to the electron beam axis behind 8mm and 23 mm absorbers. The molybdenum wires were 1 mm in diameter. The process of irradiation lasted for about 1 min. This experimental layout was chosen in order to simulate certain parameters when designing the ^{99}Mo production. The level of induced activity in molybdenum specimens was measured by standard means. Fig. 2 shows the induced activity level as a function of time after turning-off the beam. Curves 1,2 and 3 correspond to the activity levels of specimens 1, 2 and 3 in Fig. 1, respectively. Two hours after turning-off the beam, the activity level of specimens 1, 2 and 3 decreases by a factor of about 35 as compared to the initial level. Only the radioactive decay of ^{99}Mo and ^{99m}Tc corresponds to the behavior of the curve two hours after turning off the accelerator. A Ge(Li) detector was used to detect high energy gamma-quanta within 4 hours after the turn-off. ^{93m}Mo was not observed.

To improve the experimental accuracy, natural molybdenum was irradiated by a 12 MeV electron beam for 20 hours. The reaction thresholds E_n are:

$$^{100}\mathrm{Mo}\ (\gamma,\mathrm{n})^{99}\mathrm{Mo},\ E_n = 9.1\ \mathrm{MeV}$$

$$^{94}\mathrm{Mo}\ (\gamma,\mathrm{n})^{93m}\mathrm{Mo},\ E_n = 9.7\ \mathrm{MeV}.$$

The thresholds of generation of other isotopes are above 12 MeV. The Ge(Li) detector with a volume of 50 cm^3 was used to detect gamma-quanta. In this experiment ^{93m}Mo was also not observed. These results have been used to design the radiation shielding container.

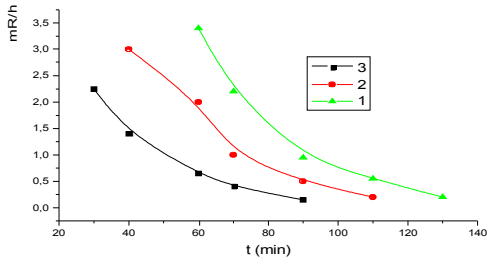

Fig.2. The induced activity versus time after the beam turn-off.

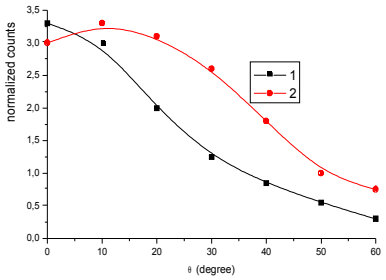

Fig. 3. Angular distribution of gamma rays. 1 - experiment, 2 - calculation

Fig. 3 shows the angular distribution of gamma rays. The 22 MeV electron beam was converted on a thick target. Curve 1 shows the angular distribution of gamma rays with an energy higher than 9.1 MeV from molybdenum specimens. The production of ^{99}Mo at an angle of 30° is a third of that at 0°. Curve 2 shows the angular distribution of gamma rays with energies ranging from 0 to 22 MeV, computed by the GEANT code for the given experimental conditions. It is seen that there is correlation between the ^{99}Mo production and the angular distribution of gamma-rays. The discrepancy between curve 1 and curve 2 can be attributed to the fact that the experimental spectrum of gamma-rays was measured from 9.1 MeV to 22 MeV, while the theoretical spectrum was computed for the energy range from 0 to 22 MeV. The results are used for deciding on the geometrical dimensions of the target.

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